A WATER QUALITY INVENTORY AS RELATED TO LAND USE ON A DIVERSELY DEVELOPED WATERSHED
PHASE II

COMPLETION REPORT

A Water Quality Inventory as Related to Land Use on a Diversely Developed Watershed

Phase II

December 1979

Prepared by

Peter J. Gowen and Stanley L. Ponce

INTRODUCTION

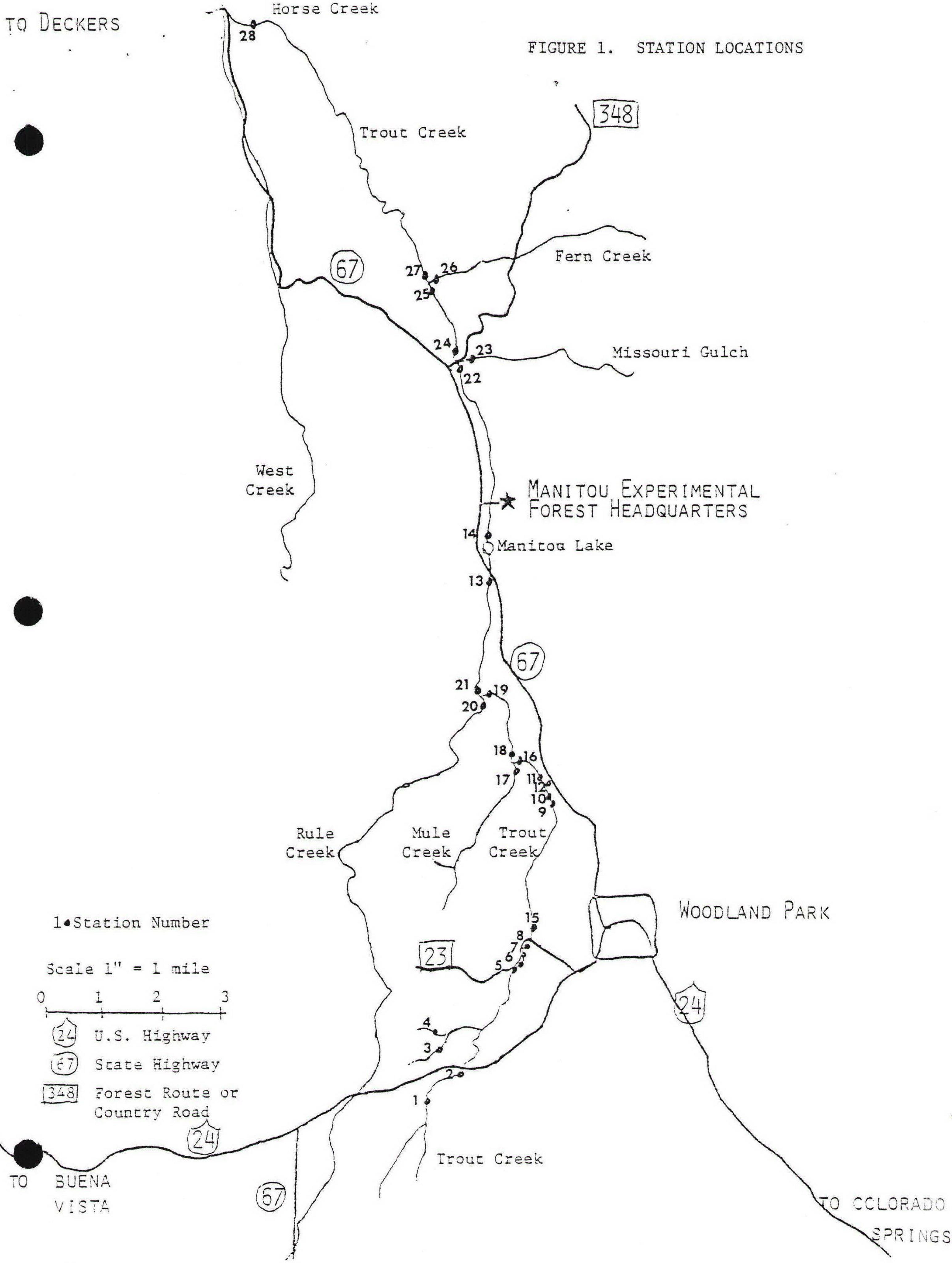
The purpose of this study is to characterize the surface water quality of Trout Creek and to assess the water quality impacts of several land uses occurring within the watershed. Several springs and major tributaries have been monitored in conjunction with other sites along Trout Creek to assess temporal and spatial changes in water quality within the Trout Creek drainage.

This report summarizes the work accomplished during the 1979 field season. Departures from the original Study Plan submitted May 1, 1979 are explained as well as major difficulties encountered either in the field or lab. Trends within the Trout Creek watershed and at the specific treatment sites are summarized. A more detailed analysis will be presented upon the completion of the second sampling field season (Phase III of the study).

STATION ESTABLISHMENT

All stations described in the Study Plan were established. Specific treatment areas include: intensive grazing at the Glenn Johnson Ranch near Divide, Colorado; road fill encroachment along Country Road 23; sewage treatment lagoon effluent along Trout Creek north of Woodland Park; intensive day use recreation at the Manitou Lake Picnic area. Several other stations were established at two springs on the Glenn Johnson Ranch at the confluence of Trout Creek with Mule, Rule and West Creeks to further characterize the water quality of the Trout Creek watershed. Figure 1 illustrates approximate station locations within the watershed.

FIGURE 1. STATION LOCATIONS



During most of the summer, nutrient and bacteria samples at the lower lake site were collected 50 meters downstream of the dam, at the point of the discharge measurement. In order to provide a more representative sample of the lake quality, supplemental bacteria and nutrient samples were collected late summer from the top of the dam.

Station 9 was established approximately 100 meters upstream of Station 10. It was intended in the Study Plan to locate Station 9 nearly 0.5 kilometer upstream from the first lagoon at a point where a dirt road crosses Trout Creek. Access problems prevented locating the station as originally planned. Discharge measurements late in the summer were discontinued at Station 9 when aquatic plants made the measurement impossible under the low flow conditions. Discharge at Station 9 was presumed to be equivalent to measurements made approximately 100 meters downstream at Station 10. A paired t-test made on the discharge measurements early in the season at these two stations demonstrated that these discharges can be considered equivalent at the 90% confidence level. Similar statistical tests on the water quality constituents reveal that in general, these two sites may be considered duplicates of the same station.

METHODS AND PROCEDURES

Field and laboratory procedures followed those outlined in the Study Plan of May 1, 1979 with the following minor variations. To the extent practical, measurements at each station were made at the same point each visit. Deviations from this practice were made under low

flow conditions where cross sections were selected either slightly above or downstream from the original site so that discharge could be measured more accurately. Low flow at Station 2 were collected in a bucket and timed by a stopwatch as the water flowed out of the culvert. The total discharge for the given time was then measured in the field with a 1 liter graduated cylinder.

During the low flow period of late summer, the USGS DH-48 sediment sampler could not be used. Depth integrated samples were instead collected by lowering the sampling bottle slowly into the stream with several fingers held over the mouth of the bottle to delay the water entrance. The suspended solids sample was collected from the entire cross-section. Bedload was no longer measurable after mid-July.

The initial suspended solids analysis were deemed unreliable due to a filter problem early in the study. This was resolved, and reliable results were first obtained in late June.

Nitrate and orthophosphate samples were not collected in acid-washed bottles, but instead were taken from the suspended solids sample. Each bottle was rinsed three times with the stream water immediately prior to samples collection. Samples were chilled immediately in the field and held in the refrigerator upon return to the laboratory where analyses were performed roughly within 24 hours.

Cross-section measurements of stream channel configuration at the road encroachment area were not made as originally planned. Although this method originally seemed very well suited for sediment source calculations, latter field observations of country road maintanance procedures nullified its value. As a result, a photographic record was made of the stream banks throughout the summer.

Initially, quality control procedures, particularly with nitrate and orthophosphate, were applied rigorously. All samples and standards were run in triplicate. Several standard dilutions were run each time a set of unknown samples were analyzed. Nutrient concentrations from most of the stations were below the limit of reasonable detection (% transmittance greater than 90%). As a result, it was decided to reduce the number of duplicates and standards analyzed. Starting in July, only single samples were run on nutrients unless unexpected low transmittance readings were obtained, in which case duplicates or triplicates were run.

ANOVA sampling of nutrients revealed major variations within the analytical procedures. While analyzing standard concentrations, variations in % transmittance were as high as 20% at a single concentration despite careful efforts to prepare the standards properly. This results in very wide confidence intervals for any value on the calibration curves. Since the calibration curves rapidly lost lineality at percent transmittances below 20% and above 90%, samples with transmittances less than 20% were diluted to half their transmittances in a more sensitive range and all values with % transmittances greater than 90% were considered less than detectable. Discussions are in progress with Hach Chemical Company as to whether the sensitivity of the nutrient procedures may be improved.

SAMPLING FREQUENCY

Primary stations were sampled on a weekly basis while secondary stations were sampled every other week. Tertiary stations were sampled a minimum of once per month while several were sampled on a bi-weekly

basis. Three stations (Elk Park, Site 15; Mule Creek, Site 17, and Missouri Gulch, Site 23) dried up during the course of the summer. Although Trout Creek dried up approximately 0.5 kilometers upstream of the lagoon sites, several large springs within a couple hundred meters of the lagoon sites sustained streamflow at the lagoon sites throughout the summer. A listing of stations along with their sampling regime is presented in Table 1.

Special sampling was conducted on those weeks where only the primary stations were scheduled. This consisted of ANOVA sampling at the grazing treatment sites once, ANOVA sampling at the road sites twice, diurnal sampling of bacteria at the lake sites twice and triplicate sampling of bacterial and nutrients at the lagoon sites once. Storm sampling was conducted once at the grazing sites and twice at the road sites. Additional storm sampling visits were made to the road sites, but on both occasions the particular storm did not affect the flow at the sampling site despite substantial rains at both the Manitou Experimental Station and Woodland Park. At least two major storms affecting the road sites were missed. One storm occurred during a weekend when both members of the field crew were away from the area while the other was highly localized and struck the road area without any indication at the Experiment Station where the field crew was located. Several pictures were taken at the road sites after these events in an effort to visually document storm damage. Miscellaneous samples were collected occasionally at various sites whenever curiosity warranted.

A brief summary of each day's activity was recorded in a research notebook. Included in this quasi-diary are a listing of stations visited,

TABLE 1

SAMPLING STATIONS AND IMPLEMENTED SAMPLING SCHEME (1979)

Station Number	Station	Class	BL	SS	TDS	TEMP	EC	NO_3	PO_4	FC/FS	FLOW
1	Upper Glen Johnson	1		1	1	1	1	1	1	1	1
2	Lower Glen Johnson	1		1	1	1	1	1	1	1	1
3	GJ Spring 1	3			3	3	3	3	3	3	
4	GJ Spring 2	3			3	3	3	3	3	3	
5	Road 1	1	1	1	1	1	1				1
6	Road 2	1	1	1	1	1	1				1
7	Road 3	1	1	1	1	1	1				1
8	Road 4	1	1	1	1	1	1	1	1	1	1
9	Lagoon 1	1		2	1	1	1	1	1	1	1
10	Lagoon 2	1		2	1	1	1	1	1	1	1
11	Lagoon 3	1		2	1	1	1	1	1	1	1
12	Lagoon 4	1			1	1	1	1	1	1	
13	Upper Lake	1	4	1	1	1	1	1	1	1	1
14	Lower Lake	1		1	1	1	1	1	1	1	1
15	Trout Creek at Elk Park	4		4	4	4	4	4	4	4	
16	Trout above Mule	2		2	2	2	2	2	2	2	2
17	Mule	2		2	2	2	2	2	2	2	2
18	Trout below Mule	3		3	3	3	3	3	3	3	3
19	Trout above Rule	2		2	2	2	2	2	2	2	2
20	Rule	2		2	2	2	2	2	2	2	2
21	Trout below Rule	3		3	3	3	3	3	3	3	3
22	Trout above Missouri	2	4	2	2	2	2	2	2	2	2
23	Missouri Gulch	2		2	2	2	2	2	2	2	2
24	Trout below Missouri	3		3	3	3	3	3	3	3	3
25	Trout above Fern	2		2	2	2	2	2	2	2	2
26	Fern	2		2	2	2	2	2	2	2	2
27	Trout below Fern	3		3	3	3	3	3	3	3	3
28	Trout above West	2		2	2	2	2	2	2	2	2

1) Primary or weekly
2) Secondary or Bi weekly
3) Tertiary or monthly
4) Occasional

analyses performed, identification of standard solutions or prepared media, any unusual observance of the field or lab, any difficulty encountered, or anything else that might be of interest sometime in the future. Along with this research notebook, all field sheets documenting each station visit and all lab sheets for the analyses of suspended solids, total dissolved solids, bedload, nutrients, fecal coliform and fecal streptococcal bacteria have been retained. As part of the weekly routine, all data were tabulated and graphed on summary forms organized by station number and also recorded on a master FORTRAN coding sheet for each station. A copy of the raw data, organized by station number, is attached to this report (Appendix 1).

RESULTS AND DISCUSSION

Grazing Treatment

The results of the grazing treatment are summarized in Table 2. No livestock were observed during the 1979 field season in the pasture isolated for the grazing input study on the Glenn Johnson Ranch. Discharge at Station 2 was consistently lower than at Station 1 due primarily to irrigation diversions between the two stations. Suspended solids at Station 2 were consistently higher than Station 1, but the difference has little physical meaning. Specific conductance and total dissolved solids also increased from Station 1 to Station 2. This increase was primarily due to the irrigation runoff between the two stations. Nitrate and phosphate concentrations were consistantly below detectable limits. Fecal coliform and fecal streptococcal bacteria densities increased

Table 2. Summary Statistics for Grazing Sites

UGJ(1)	Discharge (l/sec)	Suspended Solids (mg/l)	Temp (°C)	Specific Conductance (μmhos/cm)	Total Dissolved Solids (mg/l)	Nitrate (μg/l)	Phosphate (mg/l)	Fecal Coliform (col/100 ml)	Fecal Streptococca (col/100 ml)
Mean	15	3	16.5	146	98	–	–	38	570
Median	21	0	17.0	142	100	–	–	24	340
Stand. Dev.	11	4	5.5	15	23	–	–	36	650
Range	1-44	0-12	8-22	120-165	64-141	<160-185	<0.1-0.18	0-123	38-2400
n	23	8	22	13	21	22	22	18	18
LGJ(2)									
Mean	7	6	16	216	143	–	–	52	1200
Median	8	2	16	215	131	–	–	22	380
Stand. Dev.	5	8	5	29	25	–	–	72	2000
Range	1-25	0-19	8-21	170-255	105-190	<150-165	<0.1-0.19	3-280	30-6700
n	23	8	22	13	21	22	22	18	18

slightly between the two stations, probably from residual fecal matter deposited during the previous winter and spring period when livestock use of the pasture was intensive.

Road Treatment

Table 3 summarizes the results of the road treatment study. Suspended solids concentrations throughout the summer were consistantly low as most of the samples reflect dry weather flow conditions. The four road stations were designed to isolate two areas where a county gravel road encroaches on the Trout Creek channel and one area where the immediate stream channel is far removed from the road. A statistically significant increase in suspended solids at the 90% confidence level was observed between the first two stations isolating the first road encroachment (Sites 5 and 6) as was a statistically significant decrease between Stations 6 and 7 which isolate the area away from the road. Similar statistical tests between Stations 7 and 8 revealed no significant difference between those two stations which isolate the second road encroachment area. While it can be said that the area between Stations 5 and 6 can be considered a source area for suspended solids and that the area between Stations 6 and 7 can be considered a sink, one must realize that the mean difference of suspended solis between the paired stations is less than the standard deviation of the test procedure. Although the differences have statistical significance they are not meaningful in a physical sense. Measurement of more wet weather flows will be needed before the results will have acceptable physical meaning.

Bedload varied considerably at each station but showed the same general pattern as the suspended solids. Massive amounts of bedload

TABLE 3

Summary Statistics for Road Sites

	Discharge (l/sec)	Suspended Solids (mg/l)	Bedload (kg/day)
R1(5)			
Mean	13	7	89
Median	3	6	68
Stand. Dev.	24	8	110
Range	1-128	0-39	0-340
n	32	27	10
R2(6)			
Mean	12	9	1000
Median	3	6	249
Stand. Dev.	19	10	2300
Range	2-94	0-45	0-7600
n	32	27	10
R3(7)			
Mean	16	7	100
Median	4	5	54
Stand. Dev.	21	9	160
Range	2-82	0-43.6	0-550
n	35	27	11
R4(8)			
Mean	16	5	100
Median	4	3	57
Stand. Dev.	20	5	110
Range	2-98	1-13	0-288.5
n	35	27	9

appeared to have been moved at both road encroachment sites during two major storms in August. Although no samples were collected during the storm event, considerable mass movement of road fill was witnessed after two storms. At the first encroachment site, Trout Creek was shifted several feet when it became temporarily dammed by the coarse sediment from the road fill. Several pools downstram of this site were completely filled in by the massive amount of bedload moved during the storm event. The impact of this storm event on the channel of Trout Creek was observed several hundred meters downstream. It was difficult to evaluate the impact of the second road encroachment site from this storm because the load from the upstream site was carried through the second site.

Lagoon Treatment

The results of the lagoon treatment are summarized in Table 4. The lagoon treatment study was complicated by the presence of livestock in the pasture where sites 9, 10 and 12 were located. Nitrate concentrations were consistantly high in Trout Creek through the lagoon treatment area ranging from 410 to 1900 $\mu g/l$ at Stations 9 and 10 and from 440 to 1300 $\mu g/l$ at Station 11 (L3). Nitrate concentration in the direct lagoon seepage (Station 12) was much lower and frequently below detectable limits. Phosphate concentrations at all sites were routinely below detectable limits. The nitrate source at the upstream sites is likely due to the grazing livestock. The fecal coliform/fecal streptoccal bacteria ratios lends support to this conclusion as the FC/FS ratio is consistantly less than 0.7 for all of the lagoon sites, even at Station 11 which was downstream of the lagoons but inaccessible to livestock.

Table 4

Summary Statistics for Lagoon Sites

	Discharge (l/sec)	Suspended Solids (mg/l)	Temp. (°C)	Specific Conductance (μmhos/cm)	Total Dissolved Solids (mg/l)	Nitrate (μg/l)	Phosphate (mg/l)	Fecal Coliform (col/100 ml)	Fecal Strep (col/100 ml)
L1(9)									
Mean	24	4	12	213	132	920	–	7	490
Median	27	3	12	210	124	780	–	2	350
Stand.Dev.	8	3	1	11	28	520	–	110	390
Range	9-39	1-10	9.5-14	195-235	93-201	480-2000	<0.1-0.23	1-350	180-1700
n	18	5	21	13	10	21	20	20	21
L2(10)									
Mean	23	3	12.5	214	134	910	–	78	360
Median	31	1	12.5	210	123	760	–	7	250
Stand.Dev.	11	3	1.5	20	33	400	–	120	320
Range	9-45	0-8	9.5-15	192-275	111-224	410-1800	<0.1-0.14	0-490	120-1600
n	23	6	23	14	10	23	22	23	24
L3(11)									
Mean	26	10	13.5	271	162	700	0.20	128	580
Median	31	10	14.0	273	161	770	0.11	24	470
Stand.Dev.	11	7	2.0	19	28	300	–	220	360
Range	8-50	0-22	9-15	230-290	113-223	440-1300	<0.1-0.46	5-960	180-1600
n	23	9	22	14	11	23	22	22	24
L4(12)									
Mean	–	–	13	756	410	–	–	600	4100
Median	–	–	13	710	406	–	–	69	2200
Stand.Dev.	–	–	2	64	27	–	–	1100	9100
Range	–	–	10-16	650-850	360-445	<160-200	<0.1-0.3	30-5600	360-47000
n	–	–	13	15	11	24	23	23	23

The direct lagoon seepage total dissolved solis is much greater than that in Trout Creek. Some of this seepage is joining Trout Creek as is evidenced by the noticable increase in total dissolved solids at the downstream Station (11). Since this direct seepage is much lower in nitrate concentration, it is likely serving to help dilute the nitrate concentrations between Stations 10 and 11. Other factors including plant uptake are also working to reduce the nitrate concentrations between Stations 10 and 11.

Lake Treatment

Sampling results at the lake treatment area are summarized in Table 5. Sampling 50 meters below the dam at the lower lake Station (14) resulted in very few samples taken at the station being representative of the lake. The bacteria samples collected at the top of the dam were substantially lower than those taken at the same time at the upper lake station. Nitrates and phosphates were consistantly below detectable limits. Specific conductance remained very similar between the two lake stations with only a minor variation in total dissolved solids.

Discharge increased between the two lake stations. The upstream station could not be located such that it could measure the total surface flow into the lake, but observations during the low period lead to the conclusion that this fact alone does not account for the increased measured flow out of the lake compared to the measured inflow. The difference between measured inflow and outflow was most pronounced when the flow at the upper station was nearly absent. A logical conclusion is that there is a substantial groundwater inflow to the lake. This observation is also supported by staff of the Pike National Forest.

Substantial increases in bacteria densities were obtained between the top of the dam and 50 meters downstream of the dam at the lower lake site. Paired observations of fecal coliform and fecal strep densities are presented in Table 6. The cause of this dramatic increase in such a short distance is not known. Nutrients, specific conductance and total dissolved solids measured at the same two sites simultaneously were essentially identical.

Table 5

Summary Statistics for Lake Sites

	Discharge (l/sec)	Suspended Solids (mg/l)	Specific Conductance (μmhos/cm)	Total Dissolved Solids (mg/l)	Nitrate (μg/l)	Phosphate (mg/l)	Fecal Coliform (col/100 ml)	Fecal Strep (col/100 ml)
UL(13)								
Mean	59	2	264	166	<150	-	35	370
Median	7	1	270	170	<150	-	29	250
Stand. Dev.	96	2	43	25	-	-	29	380
Range	1-336	0-5.6	196-345	122-199	<150	<0.1-0.17	2-102	27-1700
n	17	10	13	15	19	18	30	31
LL(14)-Dam								
Mean								
Median								
Stand. Dev.								
Range								
n								
LL (Below Dam)								
Mean	68	6	264	156	-	-	210	4200
Median	23	7	263	161	-	-	150	3200
Stand. Dev.	91	3	33	19	-	-	240	4400
Range	13-325	2-10	205-300	113-185	<150-205	<0.1-0.13	2-1000	16-19000
n	16	9	14	16	19	18	32	31

Table 6

Comparison of Bacteria Densities Between Lower Lake Substations

(Colonies/100 ml)		Fecal Strep (Colonies/100 ml)	
Top of Dam	50 meters downstream of dam	Top of Dam	50 meters downstream of dam
4	525	80	4500
3	48	23	2600
1	48	22	3500
15	6		
0	2		

Trout Creek Watershed Trends

Few measured variables exhibited a marked spatial trend throughout the watershed (Table 7). Discharge increased in the downstream direction as tributaries join Trout Creek, but suspended sediment concentration varied very little (Figure 2). Most tributaries to Trout Creek had lower total dissolved solids than the main stream. This dilution affect tended to balance any tendancy for Trout Creek to increase its dissolved solids with greater hydraulic redience time progressing downstream (Figure 3). Generally, the nitrate concentration in Trout Creek was not detectable by the analytical procedure employed. The sites where it could be detected include the two spring sites on the Glenn Johnson Ranch, the lagoon sites, and Trout Creek above Mule and Rule Creeks (Figure 4). On several occasions nitrate concentrations exceeded 1000 $\mu g/l$ at the first two lagoon sites. Concentrations steadily decreased downstream until the confluence with Rule Creek where the nitrate levels were no longer detectable. When the Woodland Park sewage treatment lagoons failed in late August, the nitrate shock load was observed as far downstream as Trout Creek below the Rule Creek confluence, but could not be detected at the upper lake site.

In general, PO_4 concentrations were below the level of dection throughout the watershed with the exception of the springs and lower lagoon sites (Figure 4).

Bacteria densities varied considerably at each station with no apparent trend within the watershed (Figure 5). Tributaries all had lower coliform and strep densities than Trout Creek, but Trout Creek densities at the lower end of the watershed were not much different than the upper end. It is interesting to note that the mean of the fecal strep densities measured at the lower lake station 50 meters below the dam was roughly the same as that measured at the

FIGURE 2. MEAN SUSPENDED SOLIDS CONCENTRATION

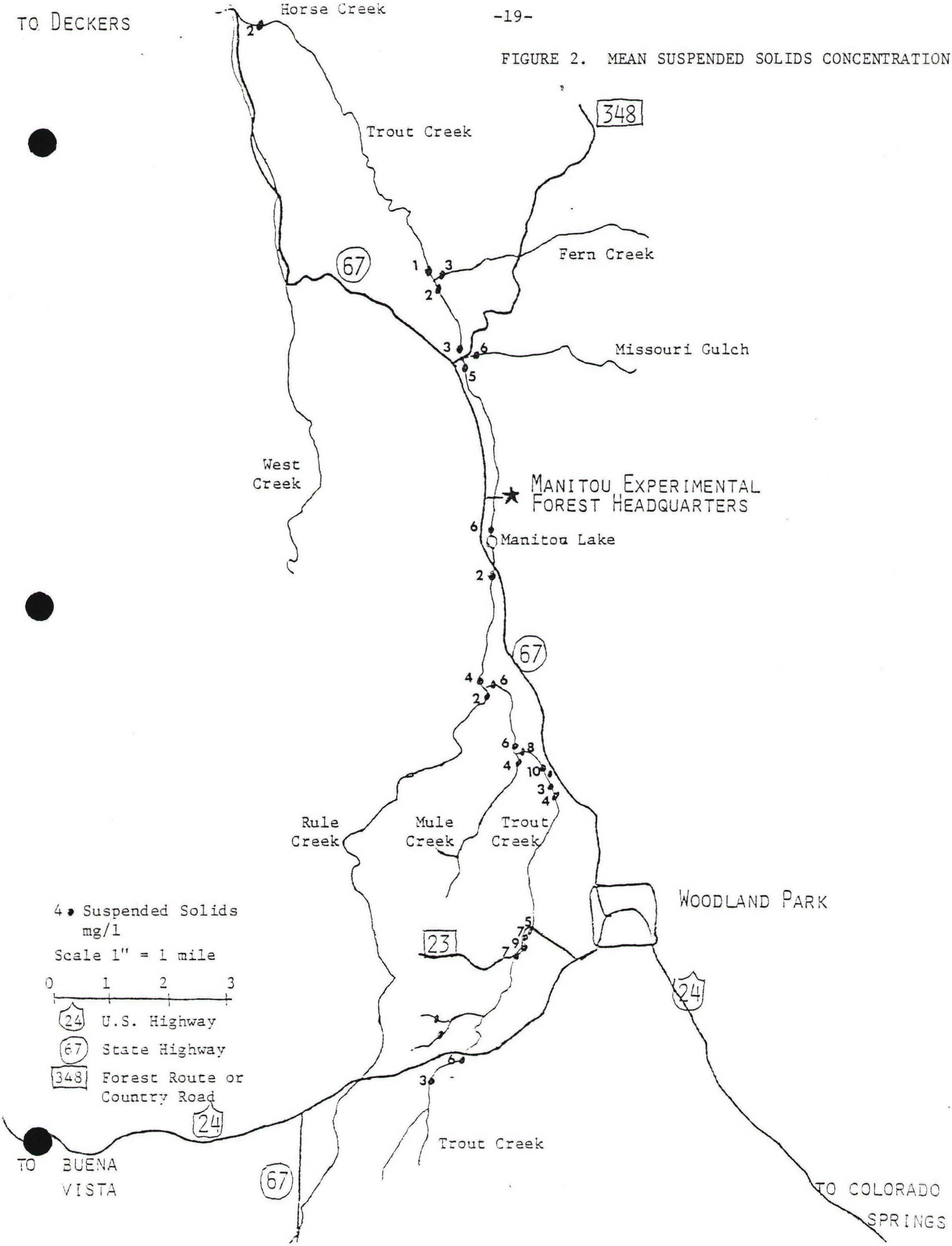


FIGURE 3. MEAN TOTAL DISSOLVED SOLIDS CONCENTRATIONS

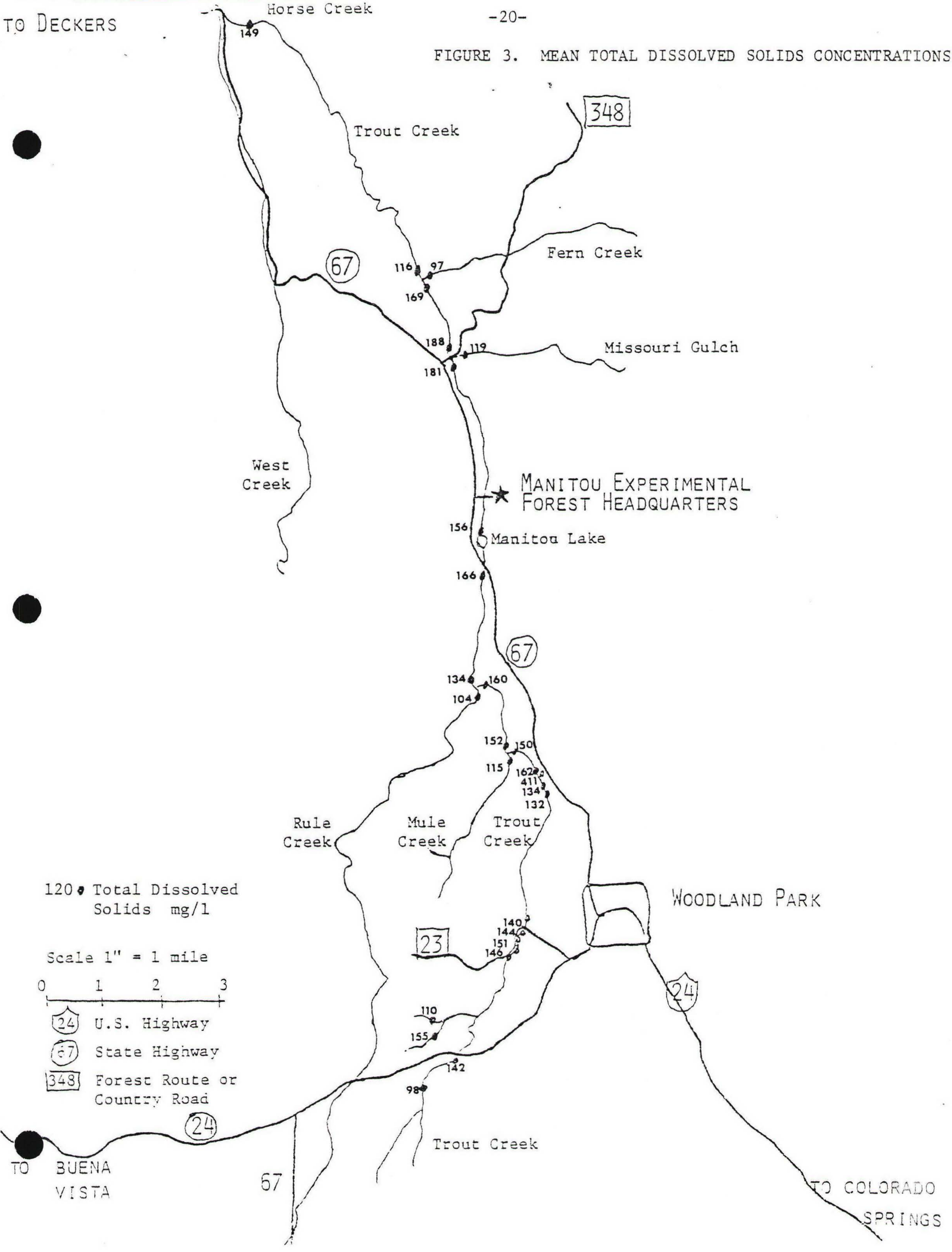


FIGURE 4. NITRATE AND PHOSPHATE MEAN CONCENTRATIONS

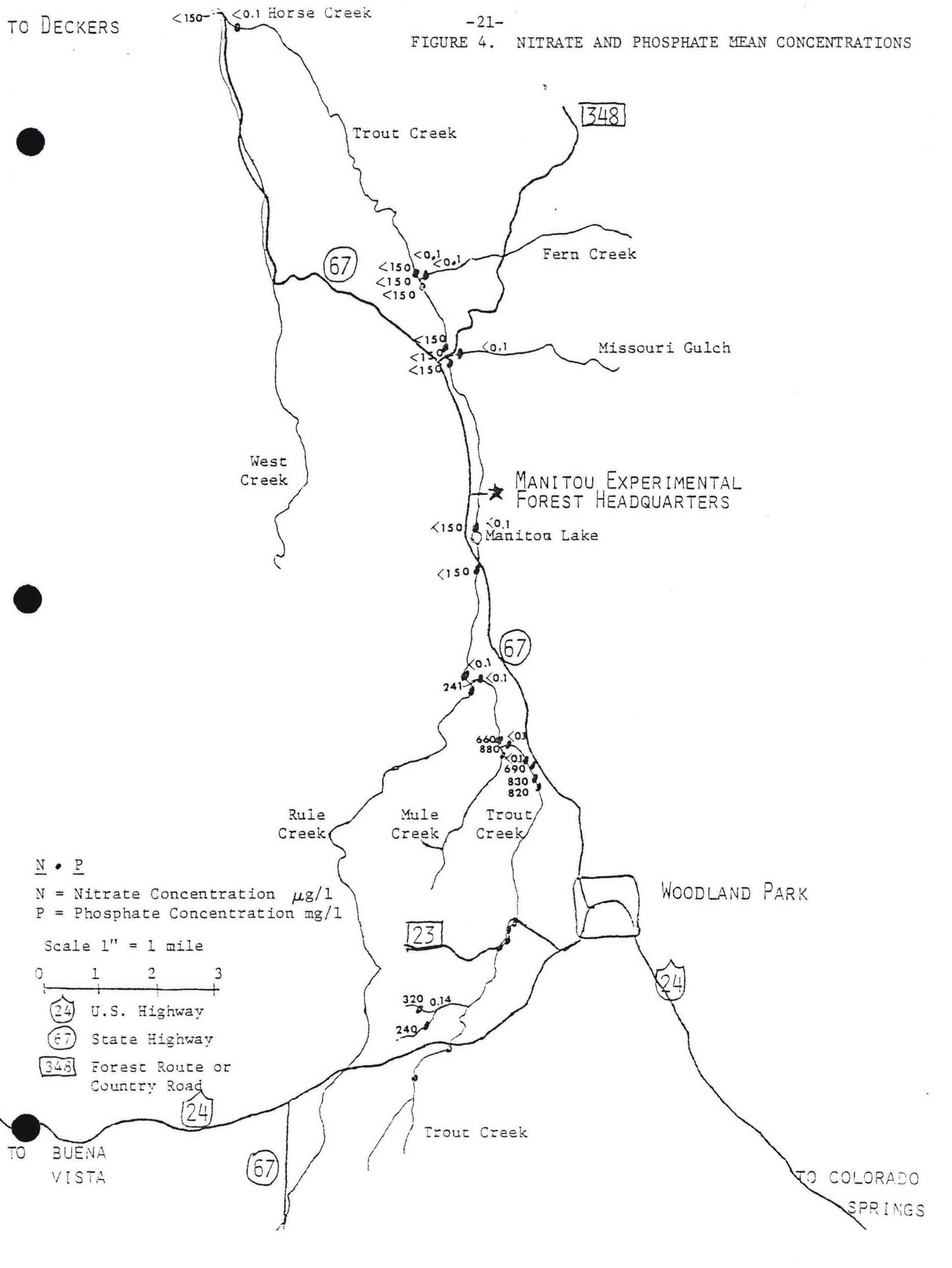


FIGURE 5. MEAN FECAL COLIFORM AND FECAL STREP DENSITIES

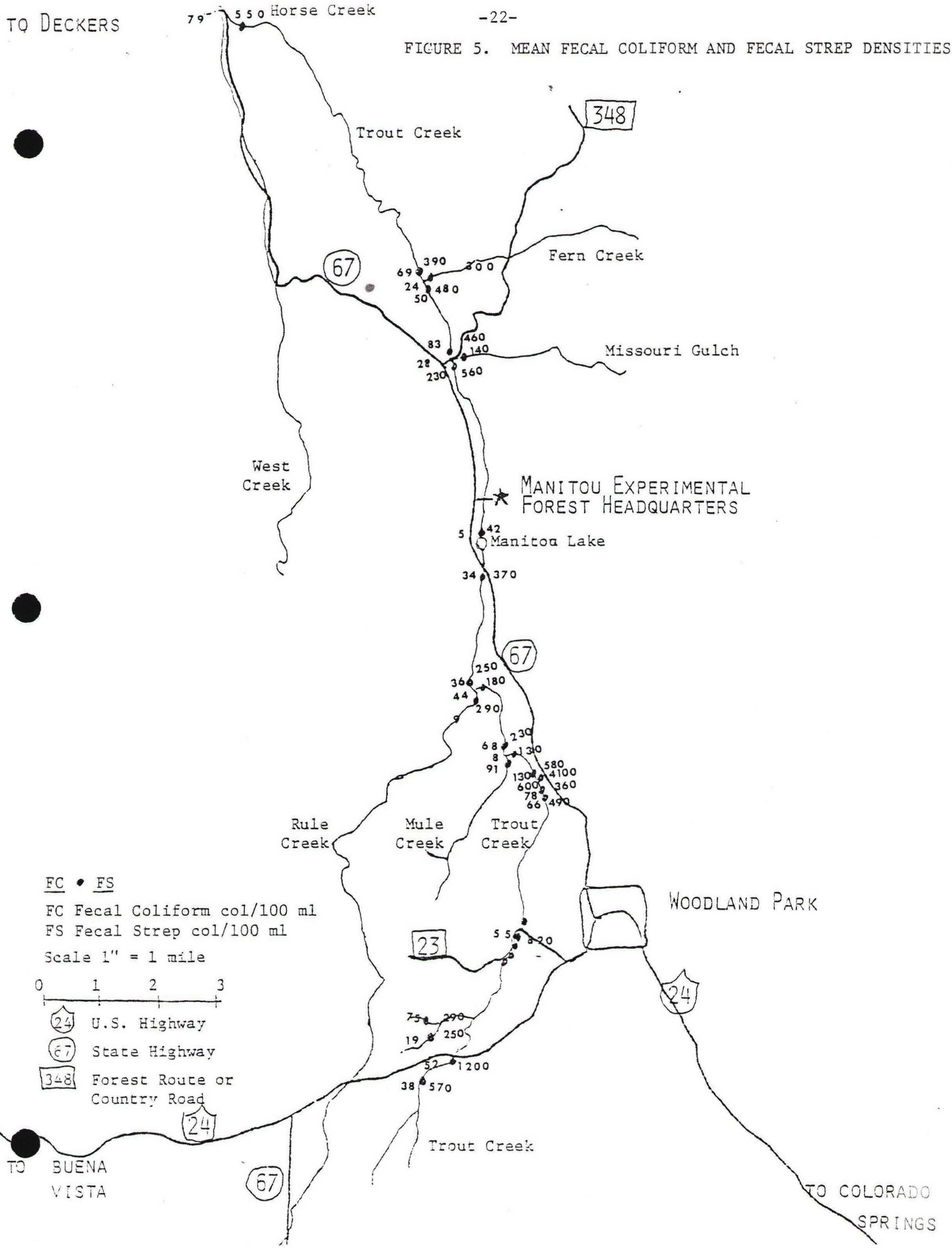


Table 7

Mean Values for Selected Variables

Sta. No.	Discharge 1/sec	Susp. Solids (mg/l)	Total Dissolved Solids (mg/l)	Nitrate (μg/l)	Phosphate (mg/l)	Fecal Coliform (col/100 ml)	Fecal Strep (col/100 ml)
1	15	3	98	-	-	38	570
2	7	6	142	-	-	52	1200
3	-	-	155	240	-	19	250
4	-	-	110	320	0.14	75	290
5	12	7	146	-	-	-	-
6	12	9	151	-	-	-	-
7	16	7	144	-	-	-	-
8	16	5	140	-	-	55	820
9	24	4	132	820	-	66	490
10	23	3	134	830	-	78	360
11	26	10	162	690	-	130	580
12	-	-	411	-	-	600	4100
13	59	-	166	<150	-	34	370
14	68	6	156	-	-	-	-
15	-	-	-	-	-	-	-
16	74	8	150	880	-	91	360
17	8	4	115	-	<0.1	8	130
18	32	6	152	66-	<0.1	68	340
19	34	6	160	241	<0.1	44	180
20	35	2	104	-	-	9	290
21	67	4	134	-	<0.1	36	250
22	68	5	181	<150	-	230	560
23	12	6	119	<150	-	28	140
24	79	3	188	<150	<0.1	83	460
25	74	2	169	<150	-	50	480
26	22	3	97	<150	<0.1	24	300
27	109	1	116	<150	<0.1	69	390
28	172	2	149	<150	<0.1	79	550

direct lagoon seepage site. The mean strep count at these two stations is nearly an order of magnitude greater than the average mean of the remaining stations.

Arizona 1936-37

Arizona 1936 - 1937
Climatological Data